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ORIGINAL ARTICLE

The influence of students' prior numeracy achievement on later numeracy achievement as a function of gender and year levels

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Abstract

Students' prior achievements in school have significant correlations with their later achievements. Specifically, students' prior numeracy achievement is the most important predictor of later numeracy success. However, the assessment of this predictor across gender and its trend across students' year levels is often overlooked or not adequately investigated. This study examined the relationships between prior numeracy achievement and its influence on students' later numeracy achievement across gender. A focus on students' year level also supported this examination. The data source was the Australian National Assessment Program—Literacy and Numeracy (NAPLAN) numeracy results of Years 5, 7 and 9 students (ages 9 to 14) from the 2017 to 2021 test years. The NAPLAN numeracy scores were analysed using regression analysis. The author examined prior numeracy achievement to determine the predictive value for students' numeracy performance in NAPLAN across students' year levels and gender. Findings from this study indicate that prior NAPLAN numeracy results for students were found to be very large in its predictive value (between $R^2 = .591$ and .747) across the year levels. Notably, the predictive value showed an increasing pattern as students progressed through their academic years. Additionally, the study observed a discernible influence of gender on the predictive value of prior numeracy results. Potential initiatives to assist the educational outcomes of students across gender are discussed. Awareness of the influence of numeracy performance across gender might help teachers and educators create better and more efficient mathematics programs and targeted interventions. Such a decision requires identifying the relevant factors and measuring their degree of influence across students' year levels and gender.

Keywords Assessment · Gender · Later numeracy achievement · Predictors · Prior numeracy achievement · Year level

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Introduction

Recent studies have suggested that there is a closing of the gender gap in numeracy achievement between male and female students (e.g. Leder & Forgasz, 2018; Perez Mejias et al., 2021; Reilly et al., 2019). As this gap diminishes, it remains crucial to recognise that gender differences in numeracy achievement hold significant implications for the underrepresentation of girls in mathematics and science fields at the secondary and tertiary education levels. The gender gap appears to vary between the prior and later stages of students' education. These gender differences in numeracy achievement are thought to increase in higher education levels due to their previous successes or failures (Hemmings & Kay, 2010; Penner & Paret, 2008; Perez Mejias et al., 2021; Steegh et al., 2019). For example, in their comprehensive systematic review, Steegh et al. (2019) suggest that gendered patterns in mathematics achievement begin to emerge early in childhood and continue to develop over time. Similarly, in a study by Perez Mejias et al.(2021), there was a noticeable gender difference in numeracy achievement among students. This difference tended to become more pronounced as the students progressed through their schooling. Such differences require investigation and intervention as prior achievement gaps lead to more significant disparities in later achievement (e.g. Getenet & Beswick, 2021; Hemmings & Kay, 2010).

Several study results have suggested that failure to obtain numeracy skills during prior grades substantially limits later opportunities for numeracy learning (Getenet & Beswick, 2021; Claessens & Engel, 2013; Mulligan, 2011). Additionally, longitudinal studies have emphasised the significance of numeracy and mathematical development during the early years and their impact on the transition from primary to secondary education (Aunio & Niemivirta, 2010; Mulligan, 2011). These findings highlighted the critical role of early numeracy education in laying a strong foundation for future learning and academic success. For example, Mulligan (2011) revealed that the gap between students' achievement becomes wider as students grow older. These differences can be influenced by various factors, such as gender (e.g. Levine & Pantoja, 2021), geographic location (e.g. Forgasz & Hill, 2013), parents' educational background (e.g. Magnuson, 2007) and students who have a language background other than English (LBOTE) (Creagh, 2014, 2016). In the Australian school context, national reports from the National Assessment Program—Literacy and Numeracy (NAPLAN) have consistently shown similar factors influencing mean variations among groups of students in their numeracy scores (Australian Curriculum and Assessment Reporting Authority [ACARA], 2017, 2018, 2019, 2021). Among these factors, it is evident that prior numeracy achievement is an essential and influential predictor of students' later numeracy achievement (e.g. Getenet & Beswick, 2021; Hemmings & Kay, 2010; Hemmings et al., 2011). Concerning prior numeracy achievement, Getenet and Beswick (2021) showed that prior numeracy achievement accounts for more than 48% of the influence on students' later numeracy achievement. In addition, a significant and high correlation was found between students' current and prior numeracy achievements.

However, the influence of prior numeracy achievement is not often studied across gender and various year levels. Furthermore, there is a lack of substantial research

conducted on this specific topic, with no large-scale studies available to investigate and provide support for this line of inquiry. In this study, the author examined the relationships between prior numeracy achievement and its impact on students' later numeracy achievement across gender. A focus on year levels also supported this examination.

The research questions guiding this study were as follows:

A) How does prior numeracy achievement influence students' later numeracy achievements as a function of gender?
B) How is the pattern of this influence explained across students' year levels?

Regardless of gender differences in numeracy achievement, investigating the predictive value of prior numeracy achievement on later achievement offers valuable insights for educators and policymakers. This investigation is crucial for identifying effective strategies to enhance numeracy skills, understanding the mechanisms of development, and allocating educational resources. By examining the longitudinal effects of early numeracy experiences, researchers can identify trends in mathematical progress and areas for improvement, informing teaching practices and policies. Additionally, this line of inquiry can help to identify the unique contribution of prior numeracy achievement to later achievement and its relationship with other factors, such as socioeconomic status. As a result, this study aims to make three main contributions. Firstly, to assess the impact of prior achievement as a predictor on students' later numeracy achievement, taking into account gender differences, using a large representative sample. Many previous studies in this area have been limited by small sample sizes or have not specifically focused on gender differences (e.g. Hemmings & Kay, 2010; Levine et al., 1999, 2016). Second, in addition to comparing differences in the predictive value of prior achievement across gender, the study examines the differences across students' year levels. Focusing on differences across the year levels and test years is particularly important in identifying trends such as when students move from primary to secondary school and their consistency across the test years. Third, the findings regarding gender and year level differences have important implications for policies aimed at eliminating the gap in numeracy achievement. By exploring the most influential predictive factor across gender and year levels, this research provides insights to support underrepresented groups in numeracy studies at higher levels of education. It also assists in making informed decisions regarding targeted funding and interventions, by identifying relevant factors and measuring their impact across various demographic factors such as gender and year levels.

Literature review

This study examined the relationships between prior numeracy achievement and its influence on students' later numeracy achievement across gender and year levels. As a result, three themes informed the study: the importance of numeracy in education: definitions, strategies, and assessment approaches; factors influencing numeracy achievement; and numeracy achievement indicators and their level of influence. Each theme is discussed in the following section.

The importance of numeracy in education: definitions, strategies and assessment approaches

Developing students' numeracy and enhancing their ability to access, use, and interpret mathematical information is a priority in many countries. As a result, countries such as Australia (ACARA, 2019), the USA (Ford, 2018), the UK (Brown et al., 1998), South Africa (Modisaotsile, 2012) and many European countries (Parveva et al., 2011) have integrated numeracy into their school curricula to develop students' numeracy skills and make a positive contribution to society. These opportunities can help students recognise the interconnected nature of mathematics with other non-mathematics curriculum areas and its application in the wider world (e.g. ACARA, 2019; Bennison, 2015; Ford, 2018).

Numeracy was first introduced in the UK and defined as the mirror image of literacy involving quantitative thinking (Goos et al., 2019). In 1998, Brown et al. further explained numeracy emphasising basic numerical skills such as mental and written calculations and knowledge of number facts used in various contexts. The New Zealand Ministry of Education defined numeracy as using mathematics at home and working in the community considering context as an essential element (Neil, 2001). It is also defined as the ability to understand basic mathematical ideas to cope with and use the demands of today's society in daily and routine decisions confidently.

The widely accepted definition of numeracy was formulated at the May 1997 National Numeracy Education Strategy Conference held in Fremantle, Australia, resulting in the conference report titled Numeracy = everyone's business. The report defined being numerate as being able " to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life" (Department of Employment, Education, Training and Youth Affairs [DEETYA], 1997, p.15). Educators and policymakers in Australia currently embrace this broad interpretation of numeracy, which is similar to the definition provided by The Organisation for Economic Co-operation and Development (OECD). The OCED (2012) defined numeracy as mathematical literacy, which is an individual's capacity to formulate, employ and interpret mathematics in various contexts. In Australia, numeracy encompasses the knowledge, skills, behaviours and dispositions that students need to use mathematics purposefully in multiple contexts relevant to their lives in a wide range of situations in their lives (Forgasz et al., 2017; Young-Loveridge et al., 2012).

Various strategies and approaches have been implemented across the globe to enhance and assess students' numeracy skills. These strategies and approaches allow students to transfer their mathematical knowledge and skills to contexts outside the mathematics classroom (Bennison, 2015; Mathieson & Homer, 2021; Thornton & Hogan, 2004). In some countries, such as South Africa, numeracy skill is described as having the ability and confidence to think numerically and critically analyse everyday situations (Modisaotsile, 2012). As a result, schools in South Africa uniquely approached and taught numeracy as a subject known as mathematical literacy which is structured as an alternative option to mathematics (Graven & Buytenhuys, 2010). Australia and Ireland follow the concept of embedding numeracy across curriculum areas, which differs from South Africa's approach. For example, Ireland's

government placed a renewed focus on the teaching and learning of numeracy across curriculum areas with the publication of a national strategy in 2011 (Coffey & Sharpe, 2021).

To achieve public and government demands for educational accountability and standards monitoring, both the Australian and UK governments have implemented programs for assessing students with data made publicly available. In Australia, a student's numeracy skill and development is assessed in years 3, 5, 7 and 9 through the national testing system called the National Assessment Program—Literacy and Numeracy (NAPLAN) (National Assessment Program [NAP], 2022). The NAPLAN is an annual standardised national test of Australian students in years 3, 5, 7 and 9 which was implemented in 2008. The NAPLAN results provide a snapshot of a child's achievement of fundamental literacy and numeracy skills at a single point in time (NAP, 2022). However, this data has also contributed to make decisions that impact students', teachers' and institutions' practices (Hemmings & Kay, 2010). Further information about the nature of the test is provided in the Method section.

Factors influencing numeracy achievement

With the rise of large-scale assessment programs worldwide, there is a need to understand the factors influencing or predicting students' achievement in these assessment results, such as numeracy achievement. Studies and reports have shown that students' numeracy achievements in international and national tests (e.g. Programme for International Student Assessment [PISA], NAPLAN and Standard Assessment Tests [in the UK]) are widening or shrinking among different groups of students because of various factors. These factors include but are not limited to school type (Levine & Pantoja, 2021), geolocation (e.g. Forgasz & Hill, 2013), parental occupation and educational background (Carmichael et al., 2014; Yeung & Conley, 2008). Carmichael et al. (2014) also found that student factors impacting numeracy achievement were gender (including Indigenous status and language background), home-school factors (including parental education and socioeconomic status) and school factors (including government or non-government schools). National reports of NAPLAN have consistently reported on factors such as gender, Indigenous status, geolocation, school type/sector, LBOTE, parental education and occupation, showing mean variations among groups of students in their current NAPLAN numeracy scores.

Gender gaps in numeracy achievement

Notably, throughout a few decades, an extensive body of literature has revealed that students' numeracy achievement varies by gender. Gender differences in numeracy achievement have long been a topical issue in education. Earlier studies showed that a gap between the achievement of boys and girls had been found, with either boys or girls showing better performance than girls or boys in certain instances (Chambers & Schreiber, 2004; Hedges & Nowell, 1995; Randhawa, 1994; Williams et al., 2016). This gender gap has been attributed to various factors, such as negative attitudes towards mathematics, societal stereotypes and cognitive mechanisms

associated with numeracy skills. Else-Quest et al. (2010) reported that negative attitudes towards mathematics among girls can impact their academic achievement. Another factor is the threat of stereotype which refers to the phenomenon in which individuals are at risk of confirming negative stereotypes about their group. In mathematics and numeracy, girls may experience negative stereotype threats about their ability in these areas, which may undermine their performance (Leder & Forgasz, 2011). Furthermore, some research suggests that cognitive differences between genders may impact numeracy achievement (Arnup et al., 2013; Hill et al., 2014; Paz-Baruch, 2022). For example, a study by Hill et al. (2014) showed that girls perform better on tasks requiring verbal reasoning, while boys perform better on tasks requiring spatial reasoning.

However, recent studies and reports have highlighted that the gender gap is narrowing (e.g. Getenet & Beswick, 2021, ACARA, 2017, 2018, 2019, 2021; Leder & Forgasz, 2018; Perez Mejias et al., 2021). For example, in the NAPLAN test results between 2017 and 2021, the difference in students' numeracy results between males and females showed that the mean scores for male students were very close to those for female students in years 5, 7 and 9 (see Table 1).

These results and other findings from international studies have demonstrated that although gender difference remains a student-related factor that influences students' numeracy achievement, the differences have been closing over time (e.g. Getenet & Beswick, 2021; Leder & Forgasz, 2018; Perez Mejias et al., 2021). However, other indicator factors include prior numeracy achievement, parents' education and occupation status, Indigenous status and school factors. In this regard, several studies have attempted to rank or categorise the factors that have the most influence on students' achievement in numeracy. The research consistently points to the importance of prior achievement in influencing students' achievement results in their later study of numeracy (Getenet & Beswick, 2021; Perez Mejias et al., 2021). As a result, prior numeracy achievement is attracting global attention as a significant predictor of students' later numeracy achievement, which is discussed further with other indicator factors in the following section.

Table 1 Mean numeracy achievement of students in years 5, 7 and 9 across gender and test years

Test year	**Gender**	Year level		
		5	**7**	**9**
2017	M	496.28	553.35	591.04
	F	487.69	550.34	586.24
2018	M	493.84	550.22	596.59
	F	484.75	538.93	588.48
2019	M	498.50	554.90	593.60
	F	486.58	545.66	583.89
2021	M	494.12	550.88	586.99
	F	480.99	541.13	580.96

Numeracy achievement indicators and their level of influence

Various international studies have shown disparities in students' numeracy achievements among different groups of students (Carmichael et al., 2014; Forgasz & Hill, 2013; Yeung & Conley, 2008). The factors impacting on students' numeracy achievements include school type, geolocation, parental occupation and educational background with different levels of influence. Studies have quantified or ordered these and other factors based on their level of influence on students' numeracy achievements and found that prior achievement in numeracy is a strong predictor of later success in numeracy, followed by parents' education and occupation status, Indigenous status and school factors, regardless of whether the student is in primary or secondary school (Getenet & Beswick, 2021; Carmichael et al., 2014; Claessens & Engel, 2013; Duncan et al., 2007; Hemmings & Kay, 2010; Huntsinger et al., 2016; Kiss et al., 2019). Specifically, several studies conducted and reported in primary and secondary school students' contexts indicated that prior achievement in numeracy is a good predictor factor for later numeracy success at schools (Getenet & Beswick, 2021; Carmichael et al., 2014; Claessens & Engel, 2013; Duncan et al., 2007; Hemmings & Kay, 2010; Huntsinger et al., 2016; Kiss et al., 2019). In their recent study, Getenet and Beswick (2021) showed that prior attainment, Indigenous status, parents' education and occupation status influence later numeracy achievement, with prior achievement significantly contributing to more than $R^2 = 0.45$ based on 3 years of numeracy test scores from 2015 ($N = 56{,}110$), 2016 ($N = 64{,}509$) and 2017 ($N = 66{,}759$). Similarly, an earlier study by Carmichael et al. (2014) showed that prior achievement with other factors, such as Indigenous status, and parents' educational and occupation status, are stronger predictors of students' later numeracy achievements than school factors, such as school sector and geolocation. Studying specific year levels, Hemmings and Kay (2010) examined the data obtained from numeracy test results conducted in early and later years of schooling and analysed the correlations between the scores to determine the relationships between them, showing the strongest correlation ($N = 100$). Hemmings and Kay (2010) found that students' year 7 numeracy test results contributed a considerable amount of the total variance in relation to their year 10 numeracy examination scores. Claessens and Engel (2013) highlighted that students' prior skills are linked to subsequent success due to their understanding of previous mathematical concepts which are the foundation and pathways towards more advanced skills. This evidence clearly shows that what students know and understand in prior years provides a useful predictor of their numeracy achievement and success in later years (Aubrey et al., 2006; Aunio & Niemivirta, 2010; Clements & Sarama, 2014).

Government reports also support this line of argument. A report released by the Australian Council for Educational Research (ACER) (2016) showed that students' prior numeracy achievement predicts their numeracy competence later in school. Similarly, NAPLAN reports consistently showed that prior achievement substantially influences a student's NAPLAN numeracy scores more than other factors (ACARA, 2018, 2019, 2021). These studies and reports supported the claim that prior achievement is a good predictor of later numeracy achievement. However, there is a dearth of published works, and there are no larger studies on whether this influence is different across gender and students' year levels, hence, this current study's focus. Exploring the influence of gender and year levels can provide

opportunities to support underrepresented groups, make targeted interventions and identify appropriate groups for funding. In this respect, funding directives according to need and the redistribution of resources to support disadvantaged students in improving their achievement in numeracy have been successful (Loughland & Thompson, 2016; MacDonald et al., 2021).

Study method

Data for the present study were drawn from NAPLAN numeracy scores of years 5, 7 and 9 students from one state in Australia. The relevant university and school authorities provided permission to conduct this study (Approval number H19REA017). The data sources, participants, procedure and data analysis method of the study are described in the following section.

Data source and participants

The data used in this study come from large-scale national numeracy assessments from one state of Australia. The author confined the analysis to one state as they were familiar with the way mathematics is taught in the state. As a result, data from years 5, 7 and 9 NAPLAN numeracy test results were used to identify predictors of this cohort of students' NAPLAN numeracy achievement across 2017, 2018, 2019 and 2021 test years. Year 3 test results were excluded from this study as this group of students does not have prior NAPLAN numeracy test results. The NAPLAN test starts at year 3 (age 8).

The NAPLAN numeracy test comprises a combination of multiple-choice and short-response questions. Depending on the year level, the test consists of 32 to 40 items and students are allocated 40 to 50 min to complete it (ACARA, 2022). The test can be taken either in a paper-and-pencil format or online. The test items from 2008 to 2016 are available on the ACARA website. The following are some examples of questions from the 2016 NAPLAN numeracy test for years 5, 7 and 9.

- Year 5: "Stef's book contains more than 324 pages but less than 342 pages. Which of the following could be the number of pages? a) 322, b) 326, c) 344, d) 346".
- Year 7: "Lisa plans to give 1/4 of her 20 books to her sister. How many books will she give her sister? a) 4, b) 5, c) 8, d) 10".
- Year 9: "Joe measures a distance to be 5 m and 12 cm. Which of these shows how Joe can write this measurement in metres? a) 5.012 m, b) 5.12 m, c) 6.12 m, d) 6.2 m".

The test reliability coefficient alphas for paper tests have consistently been high across all year levels and test years. In 2017, the coefficient was 0.90 for year 5, 0.91 for year 7 and 0.93 for year 9. In 2018, the coefficient was 0.90 across all year levels. In 2019, the coefficient was 0.90 for year 5, 0.92 for year 7 and 0.92 for year 9.

However, the coefficients were lower in the 2021 test year, with year 5 at 0.70, year 7 at 0.68 and year 9 at 0.67 (NAP, 2022).

ACARA provided de-identified student-level NAPLAN test results from 2017 to 2021, except in 2020. In 2020, the education ministers decided to cancel NAPLAN 2020 due to the COVID-19 pandemic, and no results are available for that year. The NAPLAN scales are constructed so that any given score represents the same level of achievement over time. Using a common scale that spans years 3, 5, 7 and 9 allows in individual student achievement to be monitored and reported throughout each student's years of schooling (ACARA, 2016). The demographic information for years 5, 7 and 9 student participants across gender is shown in Table 2.

As shown in Table 2, the number of male and female students participating in the numeracy test across the year levels is very close. This close difference is less than 2%, where the number of male students is mostly greater than only 1%, except in 2018 and 2021, where the number of female students is greater than that of males by 0.1%.

The procedure of the study and data analysis

The author followed a two-step process to conduct this study. First, the author identified the major predictor factors of students' NAPLAN numeracy achievement using multiple regression analysis reported in another larger study (Getenet & Beswick, 2021). In the larger study, the authors used a multiple regression model to analyse the degree of influence that various independent variables had on students' NAPLAN numeracy achievement. The order of entry in the regression model was determined based on theoretical considerations. For instance, Carmichael et al. (2014) used ecological theory to analyse the predictors of children's numeracy scores and found that Indigenous status, parents' education and occupation status had a more significant impact on children's scores than school-related factors such as sector and geolocation. Additionally, the NAPLAN reports (ACARA, 2016, 2017) have consistently shown that Indigenous

Table 2 Participant numbers (percentage) by test year, grade level and gender

Test year	Gender	Year level		
		5	**7**	**9**
2017	M	34,577 (51.8)	32,265 (51.4)	29,869 (51.1)
	F	32,182 (48.2)	30,526 (48.6)	28,550 (48.9)
	Total	66,759	62,791	58,419
2018	M	27,971 (49.9)	26,360 (50.1)	23,338 (50.3)
	F	28,062 (50.1)	26,266 (49.9)	23,082 (49.7)
	Total	56,033	52,626	46,420
2019	M	28,142 (50.1)	27,393 (50.4)	23,851 (50.3)
	F	28,047 (49.9)	26,922 (49.6)	23,522 (49.7)
	Total	56,189	54,315	47,373
2021	M	28,340 (49.9)	27,524 (50.1)	25,407 (51.3)
	F	28,488 (50.1)	27,362 (49.9)	24,093 (48.7)
	Total	56,828	54,886	49,500

status, parental education and occupation are strong indicators of mean variations in children's NAPLAN numeracy scores. However, factors such as LBOTE (language background other than English) and gender were found to have a lower mean variation.

Based on these theoretical studies, the authors in the larger study identified Indigenous status, parental education and occupation as the strongest predictors of children's current numeracy scores in NAPLAN, followed by school factors, geolocation and school type. Gender and LBOTE were considered lower predictor variables and were entered into the model last. As a result, the factors in order of their degree of influence were prior numeracy achievement, parent's education and occupation status, Indigenous status, geolocation, sector, gender and LBOTE status. Getenet and Beswick (2021) evaluated the contribution of each independent variable to the explanation of the dependent variable and found that students' prior achievements were highly correlated with their later NAPLAN numeracy results and were included in the last entry of the regression model. Prior numeracy achievement showed a significant and greater percentage contribution in predicting students' later numeracy achievement, and was consistent across four test years, as shown in Table 3.

In the present study, the author employed binary regression analysis to investigate the predictive power of prior numeracy performance on the later numeracy achievement of students, and its distinct contribution to explaining the dependent variable of students' later NAPLAN numeracy achievements, with a consideration of gender and year levels. The author specifically used binary regression for two reasons. First, it allows for analysing the association between students' prior numeracy achievement and later numeracy achievement separately for each gender or year level. By doing so, the author determined the extent to which prior numeracy achievement predicts later numeracy achievement (e.g. for boys and girls) and examined whether this relationship is stronger for one gender than the other. This analysis can identify gender differences in the relationship between prior and later numeracy achievement, which can inform interventions to improve numeracy outcomes for both genders. Second, binary regression could help to control for other relevant factors that may impact numeracy achievements, such as school factors and parental education, which can help isolate the independent contribution of prior numeracy achievement to later achievement for each gender or year level.

The test of significance between the regression values across gender and year levels was measured following the steps recommended by the UCLA Statistical Consulting Group (2021). The UCLA Statistical Consulting Group (2021) recommends measuring the significance of the difference between regression results using a dummy variable. For instance, to compare the regression coefficients of males and females, a dummy variable called the "female dummy" was created with a value of 1 for females and 0 for males. Similarly, a "male dummy" variable was created with a value of 1 for males and 0 for females. The central value of the prior numeracy

Table 3 Summary of prior numeracy percentage contribution in the regression model (Getenet & Beswick, 2021)

Test year	2014	2015	2016	2017
Contribution percentage	49.4	50.6	50.1	49.6

achievement results is then calculated by subtracting each value from the mean. Two additional variables were created by multiplying the central value by each dummy variable. These product variables provided information on prior numeracy results for each gender. The centred prior numeracy results and the product variables were then used to determine the significant difference between predictors in the regression equation. A similar process was followed to compare year level differences. Finally, the study further examined the pattern across the 2017, 2018, 2019 and 2021 test years.

The basic recommended assumptions, such as sample size, singularity, correlation and collinearity, were considered and checked before using regression analysis. These assumptions were fulfilled in all cases. For example, according to Cohen and Cohen (1983), there should be at least 20 more cases than independent variables. In addition, Ho (2006) recommended acceptable values for tolerance and variance inflation factor (VIF) greater than 0.10 and less than 10, respectively. The collinearity statistics were tested, and all were within the accepted limits. In addition, Durbin-Watson values were between 1.9 and 2.1 for all cases, and these values are acceptable as a test for serial correlation of adjacent error terms (Field, 2009). Finally, the R^2 values and ANOVA results are reported. The increase in R^2 resulting from gender and year level differences is also included to determine the influence of these factors.

Results

Table 4 presents the mean and standard deviation (SD) of current and prior NAPLAN numeracy scores across gender and year levels for four test years (2017–2021). The mean numeracy scores for both males and females consistently increased from 2017 to 2021 across all year levels.

A further mean correlation analysis showed that the influence of prior numeracy achievement on students' later numeracy NAPLAN achievement remained a high correlation result, leading to the predictive capacity of prior numeracy achievement on current numeracy achievement being very high (see Table 5). This finding is supported by the high correlation result, which indicates that the predictive capacity of prior numeracy achievement on current numeracy achievement is very high.

Furthermore, the regression analysis results reveal that prior numeracy achievement has a high predictive value ($R^2 > 0.50$) for current numeracy achievement, regardless of gender and year levels. This means that students' prior numeracy achievement is a strong predictor of their current numeracy performance.

Table 5 shows the regression results across gender and year levels in the 2017, 2018, 2019 and 2021 test years.

The results also showed that students' prior numeracy achievements were highly correlated with their later NAPLAN numeracy results. As shown in Table 5, the predictive value of students' prior numeracy achievements in each year level (years 5, 7 and 9) was significant, with a high predictive value of R^2 between 0.591–0.747. These results were consistent across the test years.

Overall, the results shown in Tables 4 and 5 suggest that students' prior numeracy achievement is a critical factor in their current numeracy performance, and it

Table 4 Student current (prior) numeracy NAPLAN mean (M) and mean difference (SD) results

Year	Gender	Year level					
		5		**7**		**9**	
		M	**SD**	**M**	**SD**	**M**	**SD**
2017	M	496.28 (398.35)	71.13 (81.90)	553.35 (491.89)	74.77 (71.87)	591.04 (545.69)	63.20 (70.35)
	F	487.69 (389.44)	62.28 (74.41)	550.34 (484.22)	66.73 (63.57)	586.24 (538.31)	58.26 (61.59)
2018	M	493.84 (403.37)	69.77 (82.30)	550.22 (495.46)	74.15 (75.33)	596.59 (551.79)	71.02 (73.34)
	F	484.75 (393.54)	61.84 (74.81)	538.93 (485.42)	65.95 (67.57)	588.48 (546.46)	64.32 (64.98)
2019	M	498.50 (407.04)	72.10 (81.17)	554.90 (496.92)	78.60 (70.80)	593.60 (554.62)	66.69 (74.24)
	F	486.58 (401.00)	63.39 (73.16)	545.66 (488.30)	71.21 (62.06)	583.89 (51.14)	59.21 (66.55)
2021	M	494.12 (403.48)	70.55 (78.76)	550.88 (499.36)	82.44 (71.78)	586.99 (55,596)	69.21 (77.88)
	F	480.99 (395.56)	64.30 (71.37)	541.13 (487.04)	72.40 (63.13)	580.96 (546.82)	60.27 (70.81)

is consistent across gender and year levels. The findings emphasise the importance of addressing students' individual learning needs and providing appropriate support and interventions to help them improve their numeracy skills.

However, a difference in the predictive value (R^2) was observed between males and females, with male results showing higher predictive values than females with a difference of $R^2 = 1–2.4\%$. For example, the predictive value of prior numeracy achievement in 2017 in year 5 was $R^2 = 0.747$, F (1, 22,499) = 18.35, $p < 0.001$ for males and $R^2 = 0.726$, F (1, 22,333) = 59,308.39, $p < 0.001$ for females. These differences are significant. The summary of R^2 changes across the gender and year levels in each test year is shown in Table 5 and Fig. 1.

As shown in Fig. 1, the study results showed an increasing trend in the R^2 values from year 5 to year 9 for both males and females, with males consistently having higher and more significant values than females across all test years. For example, in the year 2017 test results, the R^2 values for females increased from year 5 to year 9 with $R^2 = 0.591$ (year 5), $R^2 = 0.681$ (year 7) and $R^2 = 0.726$ (year 9), while males showed an increased R^2 value from year 5 to year 9 but higher than females with $R^2 = 0.615$ (year 5), $R^2 = 0.698$ (year 7) and $R^2 = 0.747$ (year 9). The pattern in the change in R^2 values across gender and year level was consistent across the test years, as shown in Fig. 2.

The results revealed a significant correlation between students' prior numeracy achievements and their later NAPLAN numeracy results. The predictive value of prior numeracy achievement was consistent across year levels and test years, indicating the importance of building a strong foundation in numeracy skills. However, the study also found that males had higher predictive values than females, suggesting the need for further investigation into potential gender differences in numeracy development.

Table 5 Years 5, 7 and 9 regression model summaries across gender and year levels

		Model summary values					ANOVA and coefficients			
Test year	Gender	R^2	Adjusted R^2	St. error	F change	Df2	Sign	*B*	*SE B*	β
Year 5										
2017	M	0.615	0.615	43.4915	44,403.407	27,801	0.000	0.681	0.003	0.784
	F	0.591	0.591	39.3043	39,073.223	27,028	0.000	0.641	0.003	0.769
2018	M	0.623	0.623	42.1033	46,194.085	27,969	0.000	0.664	0.003	0.789
	F	0.601	0.601	38.4784	42,192.971	28,060	0.000	0.634	0.003	0.775
2019	M	0.656	0.656	41.3749	53,557.637	28,140	0.000	0.712	0.003	0.810
	F	0.642	0.642	37.2714	50,345.983	28,045	0.000	0.688	0.003	0.801
2021	M	0.656	0.656	40.321	54,035.973	28,338	0.000	0.717	0.003	0.810
	F	0.648	0.648	37.35	53,2337.04	28,486	0.000	0.718	0.003	0.850
Year 7										
2017	M	0.698	0.698	40.3541	58,702.697	25,430	0.000	0.867	0.004	0.835
	F	0.681	0.681	37.1374	54,068.346	25,289	0.000	0.862	0.004	0.825
2018	M	0.677	0.677	41.5979	55,315.771	26,358	0.000	0.811	0.003	0.823
	F	0.658	0.658	37.9778	50,622.733	26,264	0.000	0.789	0.004	0.811
2019	M	0.704	0.704	41.9222	65,263.081	27,391	0.000	0.930	0.004	0.839
	F	0.702	0.702	38.2772	63,316.829	26,920	0.000	0.958	0.004	0.838
2021	M	0.701	0.701	43.983	64,627.782	27,522	0.000	0.961	0.004	0.837
	F	0.700	0.700	38.9939	63,966.421	27,360	0.000	0.959	0.004	0.837
Year 9										
2017	M	0.747	0.747	31.4754	66,380.575	22,499	0.000	0.773	0.003	0.864
	F	0.726	0.726	30.1365	59,308.39	22,333	0.000	0.803	0.003	0.852
2018	M	0.709	0.709	37.7551	569,884.327	23,336	0.000	0.821	0.003	0.842
	F	0.694	0.694	35.082	52,363.523	23,080	0.000	0.825	0.004	0.833
2019	M	0.729	0.729	34.2763	64,067.252	23,849	0.000	0.774	0.003	0.854
	F	0.720	0.72	31.0753	60,400.882	23,520	0.000	0.758	0.003	0.848
2021	M	0.695	0.695	37.5704	57,951.029	25,405	0.000	0.745	0.003	0.834
	F	0.704	0.704	32.4253	57,186.36	24,091	0.000	0.715	0.003	0.839

Discussion

The research questions guiding the study were as follows: (i) How does prior numeracy achievement influence students' later numeracy achievements as a function of gender? (ii) How is the pattern of this influence explained across students' year levels? The following discussion responds to the research questions underpinning this study.

Prior numeracy achievement and gender

The results of this study indicated a small gender gap in students' numeracy achievement across each year's levels. In addition, a significant and high correlation between students' prior and later NAPLAN numeracy achievements was found

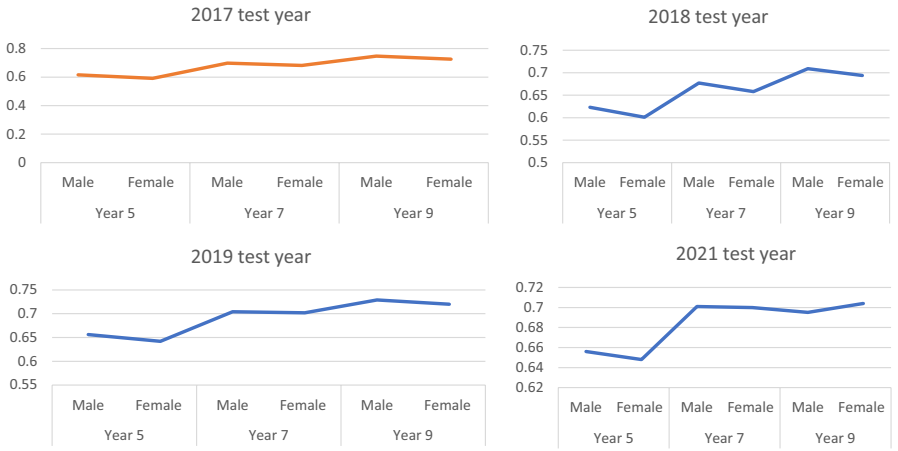

Fig. 1 Change values across gender, year level and test year

across all the year levels. This result is consistent across all the test years. That is, prior numeracy achievement was highly predicted with $R^2 > 0.50$ in relation to students' later numeracy achievement. These higher predictive values were consistent across both gender and year levels. Previous studies support these findings and demonstrate that the predictive capacity of prior students' numeracy achievement is very high in their later numeracy achievement (e.g. Getenet & Beswick, 2021; Carmichael et al., 2014; Hemmings & Kay, 2010; Huntsinger et al., 2016). In this study, however, prior numeracy results contributed higher than reported in other studies of the total variance. These results signify that those students doing less well in lower years (e.g. year 5) may need support in numeracy to improve their

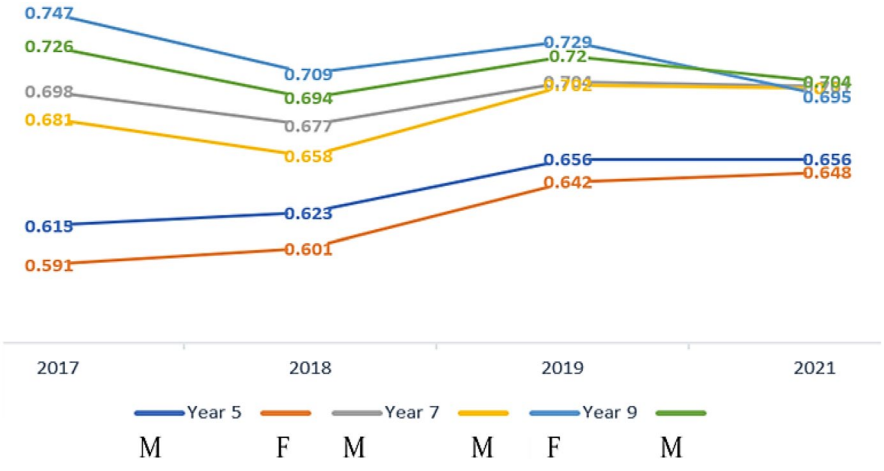

Fig. 2 $R.^2$ values across test years (M = male, F = female)

performance in year 6 and above—and will perhaps require additional help before year 5. This finding emphasises the need to develop young students' numeracy skills to ensure they experience future success. Supporting students in their prior numeracy skills can allow students to better understand the concepts and procedures needed to attain more complicated numeracy competencies in the later stage.

Unlike previous studies, this study examined the predictive values of prior numeracy achievement on later numeracy achievement across gender. Although the R^2 values increased from year 5 to year 9 for males and females (see Table 5), these values were higher for males than females, as shown in Fig. 3.

These values are consistent across test years (see Fig. 4). For this study, the results suggest that prior numeracy results influence male students' later numeracy achievements more than females. This study features boys in the literature who require support to enhance their prior numeracy skills, which could be designed with this level of influence.

The present study found a small gender gap in students' numeracy achievement across all year levels, with prior numeracy achievement highly predicting later NAPLAN numeracy achievement, indicated with R^2 values consistently above 0.50 for both males and females (Table 5). These findings are consistent with previous studies that have shown a strong predictive capacity of prior numeracy achievement on later numeracy achievement (Getenet & Beswick, 2021; Carmichael et al., 2014; Hemmings & Kay, 2010; Huntsinger et al., 2016). However, the present study found that prior numeracy achievement contributed more to the total variance in later numeracy achievement than in previous studies.

The higher predictive values for prior numeracy achievement were consistent across gender and year levels, but were found to be slightly higher for males than females (Figs. 3 and 4). This suggests that prior numeracy achievement may have a greater influence on male students' later numeracy achievement compared to

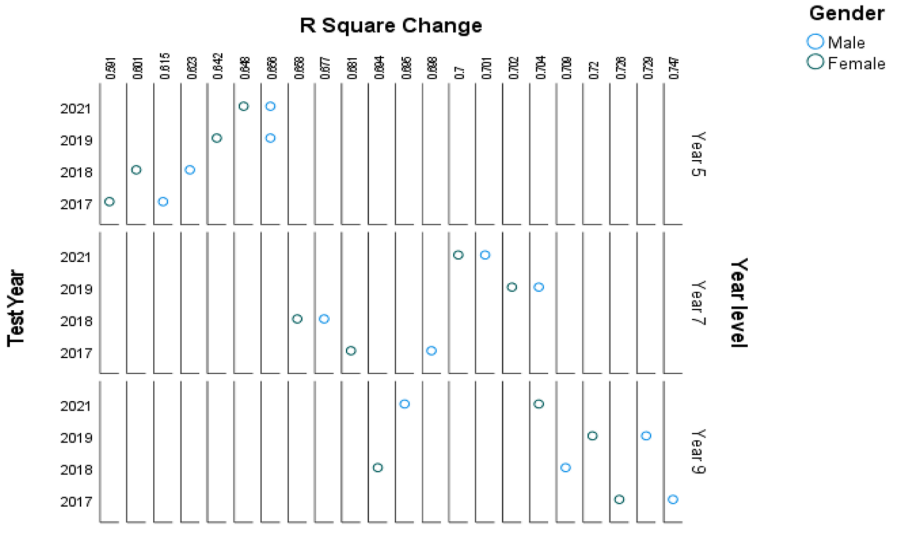

Fig. 3 R^2 changes across gender

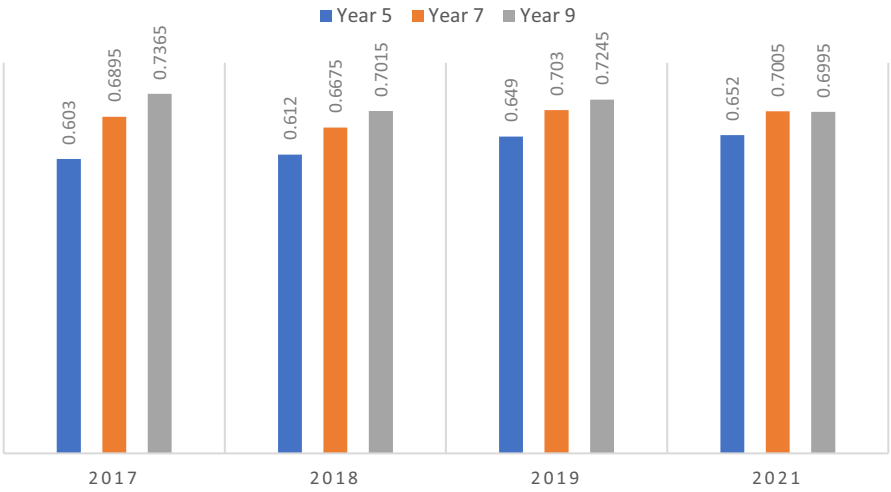

Fig. 4 The average R^2 value patterns across year levels

females. The study emphasises the importance of supporting students in developing their numeracy skills early in their schooling to enable them to achieve future success. By supporting prior numeracy skills, students can better understand the concepts and procedures needed to attain more complex numeracy competencies in later stages.

Prior numeracy achievement and year levels

In this paper, the author further analysed the influence of the predictive value of students' prior numeracy achievement on their later achievements and the changes over year levels. The results showed that predictive values appeared to change with an increased pattern between year levels. The adjusted R^2 values across year levels are shown in Fig. 4. The author of this study conducted further analysis to examine the influence of students' prior numeracy achievement on their later achievements and how it changes across different year levels. The findings revealed a pattern of increased predictive values between year levels. To illustrate this trend, the adjusted R^2 values across various year levels are depicted in Fig. 4.

As shown in Fig. 4, the R^2 values showed an increasing pattern from year 5 to year 9 except in 2021, where the R^2 values were less in year 9 than in year 7, requiring further investigation. Notably, the results of this study suggest that the effect of prior numeracy achievement on students' later numeracy achievement increased when the grade level increased and was significant. These results were consistent across the 2017, 2018, 2019 and 2021 test years. This result can help to understand the influence of prior numeracy skills across year levels. It can also allow teachers to support students to better understand the concepts and procedures needed to attain more complicated mathematical competencies beyond numeracy in the later year levels.

These results could also have implications in terms of education policies and practices including the importance of raising numeracy competency in the prior years, given that gaps that open during early school years are very hard to close later in life. Previous studies (Hemmings & Kay, 2010; Huntsinger et al., 2016) showed difficulties at a prior age in hopes of providing intervention services so that students can better develop the fundamental skills of numeracy and avoid later difficulties. Similarly, the findings of the current study suggest that students with difficulties in prior numeracy skills also tend to struggle with broader mathematical concepts later on, particularly males.

In conclusion, this study's results showed that prior numeracy achievement predicts students' later numeracy achievement at different levels in years 5, 7 and 9 and gender. These results could be used for funding and teaching support decisions so that all students have the same opportunity to progress and be successful at school (MacDonald et al., 2021). It could also support and improve funding equity and prioritise intervention activities across gender and year levels based on the magnitude of the predictor value. Some of the funding and support activities at school have been allocated to improve students' numeracy achievement, as measured by overall results (Loughland & Thompson, 2016), without considering various factors such as gender and year level differences influencing students' numeracy achievements. It is important to know the contribution level to students' numeracy achievement to help educators to identify the students likely to struggle and who will require extra support.

Limitations and future directions

It is important to acknowledge the limitations of this study. First, the study only focused on one state in Australia. To ensure that the findings are generalisable, it would be beneficial to analyse NAPLAN data from other Australian states and standardised test data from other countries. This would provide a more comprehensive understanding of the predictive value of prior numeracy achievement and performance. Second, while the study suggests that there are differences in the predictive value of prior numeracy achievement and performance based on gender and year level, the explanations for these differences may not be straightforward. There may be a complex interplay of various factors (e.g. individual differences among the participants, verbal ability and reading skills) that interact with gender and year levels to create the observed pattern of predictive factors. Therefore, relying solely on the analysis of national data through the difference in patterns may not provide a complete understanding of the underlying reasons for these differences.

To address this limitation, future studies could incorporate classroom assessment results and other countries' test results to supplement the findings of the study. By examining students' performance within individual classrooms, researchers may be able to identify additional factors that influence the predictive value of prior numeracy achievement and performance. Such an approach could provide greater insight into the factors that influence academic performance and help to inform tailored interventions to improve numeracy skills in students.

Conclusion

This study examined the relationship between prior numeracy achievement and its influence on students' later numeracy achievement across gender and year levels. The findings of this study reveal important insights into the relationship between prior and later numeracy achievement in different year levels and across gender. The results indicate that students' prior numeracy achievement significantly predicts their later numeracy achievement across all the year levels examined. The high predictive value of prior numeracy achievement is consistent with previous research, suggesting that early numeracy skills are essential for students' later success in mathematics (Getenet & Beswick, 2021; Carmichael et al., 2014; Hemmings & Kay, 2010; Huntsinger et al., 2016).

Importantly, this study contributes new information by examining the predictive values of prior numeracy achievement across gender. Although there was a small gender gap in students' numeracy achievement across all year levels, the results show that the predictive value of prior numeracy achievement is higher and more significant for male students than for female students. This highlights the need for targeted support and interventions to improve the numeracy skills of male students struggling in this area. Additionally, the study's finding that the effect of prior numeracy achievement on later numeracy achievement increases with year level underscores the importance of early intervention to support students in developing foundational numeracy skills. Focusing on differences across the year is particularly important in identifying patterns when students move from primary to secondary schools and their consistency across the test years.

The findings of this study have significant implications for education policies and practices. For instance, policymakers could use these results to allocate funding and support resources in a more targeted way to ensure that all students have equal opportunities to progress and succeed at school. Educators could use these results to identify and target students who may be struggling with numeracy and provide them with additional support and enrichment opportunities. In this way, educators can help to improve equity in education and ensure that all students have the numeracy tools they need to succeed in society.

Overall, the findings of this study highlight the importance of developing students' numeracy skills in the early years of schooling to set them up for success in later years. The study's contribution to understanding the influence of prior numeracy skills across gender and year levels is a significant step towards developing effective interventions to improve student numeracy outcomes. In conclusion, the study's findings provide valuable insights into the predictive value of prior numeracy achievement on later numeracy achievement across different year levels and gender.

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Declarations

Ethical approval The relevant University and School authorities provided ethical protocols to conduct this study with approval number H19REA017.

Competing interests The author declares no competing interests.

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